AUTOMATED MONITORING OF STORED-GRAIN INSECTS: ACOUSTICAL AND ELECTRONIC GRAIN PROBE METHODS

D. Shuman, USDA,ARS, Gainesville, FL, D.W. Hagstrum, USDA,ARS, Manhattan, KS, T.W. Phillips, USDA,ARS, Madison, WI and J.A. Coffelt, USDA,ARS, Gainesville, FL

Monitoring of insects is essential in an integrated management system for postharvest commodities. Many alternatives to methyl bromide (and other problematic fumigants and treatments) will only be financially attractive with early warning of infestation problems and elimination of unnecessary "scheduled" insect treatments. Automated monitoring systems involving computer acquisition of data from sensors distributed throughout stored commodities eliminate the need for scheduling costly manual inspections and permits access to realtime data from all storage regions. These data can alert personnel to the need for control measures and can be input directly to expert management decision support systems.

Two methods of remotely sensing insects in a wide assortment of postharvest commodities are (a) listening for movement and feeding sounds, and (b) electronic counting of insects as they enter monitoring traps. Both of these approaches are discussed here in the context of monitoring infestations in stored-grain.

An automated acoustical system has been tested in bins storing 65 to 110 tons of newly-harvested wheat on four farms in Kansas during 1992 and 1993. Seven flexible multipair shielded cables, each with 20 piezoelectric acoustic sensors attached, were installed vertically in the grain mass across the diameter of each bin. The cables ran to a central location where the individual sensor outputs were time multiplexed to a common signal line that was amplified, filtered, and connected to an electronic counter. The counter accumulated the number of times each selected sensor's acoustic signal peaks crossed a threshold voltage during 10 second intervals, and then was reset to zero. An IBM-compatible computer controlled system operation and read the counter for each sensor 27 times per day. When the system output was compared with the number of insects found in grain samples, they were correlated over the range of 0.5 to 7.5 insects per kilogram. Also, insects were not detected in grain samples until 16 to 31 days after the sounds began to increase significantly.

The Electronic Grain Probe Insect Counter (EGPIC) system is being developed to provide automated realtime monitoring of insects by using modified grain probe traps. In pest management generally, traps can be very sensitive to low insect densities because they monitor continuously and can be enhanced with chemical attractants. However, traps must be periodically inspected, which is labor intensive, limits the temporal availability of data, and restricts placement to easily accessible locations. The EGPIC system overcomes these limitations by counting insects as they drop through the probe and pass through an infrared beam. A custom infrared sensor head was designed to count stored-product insects across the full range of species' sizes. A critical sensor head design specification is protection against insects loitering around the infrared beam and producing multiple counts. Eight probes were connected to a custom circuit board comprised of a beam generation circuit, a beam interrupt detection circuit, and a computer parallel interface circuit. This circuit connects to the printer port of the computer, but could connect to an installed digital I/O board which would allow up to 90 probes to be serviced. In laboratory tests with probes inserted in infested wheat, the EGPIC counts were within 5 per cent of the numbers of insects caught. However, field tests in a flat storage of corn in

Wisconsin during 1993 found that EGPIC overestimated the actual numbers of insects passing through the probes. Grain particles and dust that passed by the sensors, and the movement of minute insects and mites back and forth over the sensors, contributed to increased counts. Additionally, beam paths became obscured with accumulated dust as sampling time progressed. Nevertheless, regression analysis revealed that EGPIC counts could reliably predict (R^2=0.897) numbers of insects entering probes across a range of insect densities. Use of a different probe body and decreases in sensor sensitivity (user adjustable) resulted in fewer grain particles entering the probe and being counted. The sensor head is currently being redesigned to reduce the possibility of insects crawling and dust accumulating in the vicinity of the infrared beam, thus increasing long-term effectiveness of EGPIC in the field.

In both of these approaches a practical consideration for a large-scale system, such as for a grain elevator, is the transmission of the data. Some of the factors involved are the number of wires from sensors to a central location, the length of the wires, and the amount of information transmitted. Related to these factors are cost and performance. For the relatively small scale systems described here, this was not an issue and the data transmission means were simple. In the case of the described acoustic system, the electronic components (amplifier, etc.) are shared by all the sensors. However, each sensor needs its own wire, the length of wire that the unamplified sensor signal can propagate through is limited, and the length of time each sensor output is attended to is inversely proportional to the number of sensors multiplexed. In the case of the described EGPIC system, the activity of each probe is immediately transmitted to the computer so that all insect counts are time-stamped, allowing for frequency analysis of the data. However, each sensor needs its own wire and the length of wire that the infrared sensor signal can propagate through is limited.

To provide a means for a large-scale system, the Serial Multiplexing Addressable Register Transmission System (SMARTS) has been developed to efficiently transfer digital data from thousands of sensors along one line to the serial port of a central computer by using a distributed multiplexing tree network. The range of SMARTS is several miles and it is relatively immune to electrical noise. The system depends upon each sensor's output signal being locally processed, digitized, and continuously accumulated in its dedicated sensor register so that sensor's output is always monitored. For the EGPIC system this would be the insect count and for the acoustic system it would be the number of 10 second intervals that had more than some fixed number of detected acoustic signal peaks. The contents of each sensor register would be transmitted by SMARTS to the computer at regular intervals whose minimum duration would be inversely proportional to the number of sensors.

Both methods of remotely sensing insects have potential in different contexts and applications and may be adaptable to other commodities. More research is also needed on how to interpret or, perhaps more importantly, how to utilize the realtime data available from these systems.